University Missions: Compatible and Complementary? Theory and Empirical Analysis Through Indicators

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Abstract: Over the last years HEIs acquired a new role in the promotion and support of regional economic development. As a consequence, and to facilitate this process, the modernization of universities ranks high in the European policy agenda. Part of this redefinition of universities roles is based on the "three mission" heuristic, namely that HEIs' contribution to economic and social development is carried out by engaging (1) teaching (2) research (3) interaction with socio-economic environment. The traditional view does not explain in detail if and how the three missions are related to one another, and that the growth of one is implicitly suggests the beneficial for the others. The present paper challenges this perspective and takes the view that university missions are constructs connected by complex relationships. In so doing, we make two contributions to the literature: first we explore the connection between the theoretical rationale of university missions, and second we assess the complementarity among missions. Our empirical study on Spanish public universities corroborates this hypothesis by finding complementarity between research (2nd mission) and interaction with the socio-economic environment (3rd mission), and substitutability between the former and teaching (1st mission). The paper calls for a critical reflection of university engagements with the missions: rethinking whether all higher education institutions should be simultaneously developing all three missions may be vital to ensuring their contribution to the socio-economic development of regions.

Keywords: university, teaching, research, third mission, complementarity, Spain.

1. Introduction

Higher Education Institutions (HEIs) have undergone structural and functional changes in recent years (Youtie and Shapira, 2008). These can be observed in the progressive transformation of the missions engaged by university from being traditionally based on teaching and research, to including a broad range of market-oriented and knowledge transfer activities. Accordingly these non-strictly-economic contributions, also known as 'third mission', have increased expectations about university as a vehicle for the development of regional innovation systems (OECD, 2007) and placed the modernization of HEIs high in the European policy agenda (EC, 2006). But prior to said modernization, we argue, it is crucial to understand the nature of and the relations across HEIs´ functions.

The present paper offers a broader perspective based on the idea that university missions are constructs connected by complex relationships of complementarity or substitutability. Building on this the paper also offers a critical reflection as on whether it the expectation that university engage all of them simultaneously is realistic.

The integration of research and the third mission implicitly assumes compatibility, and even complementarity, across all missions (Geuna, 1999; Etzkowitz, 2004). Theoretical studies argue the need for a closer relationship among the missions (Ormerod, 1996) for a proper contribution of HEIs to the development of modern knowledge-based societies and economies. However few studies test their relationship from an empirical point of view (Landry et al., 2010; Palomares-Montero et al., 2012) and rather focus on the relationship between specific activities (which are treated as proxies) as a part of an overall mission and little attention has been paid to the tensions between properly missions.

A major barrier to understanding missions is the connection between the theoretical rationale of university and the practical implementation of indicators for their measurement (Molas-Gallart, 2002). Being HEIs complex organizations, indicators measure the multitude of activities which they engage. The study of university missions is mostly theoretical given that the concept of mission is rather abstract and difficult to measure. Empirical studies need indicators to measure the different activities that HEI engage in (Molas-Gallart, 2002). However the indicators in the literature contribute to a scattered and incoherent picture and a lack of consensus about their development (Bonaccorsi and Daraio, 2007) and use. Treating missions as a construct implies knowledge about which indicators are the most appropriate for their identification.

This work elaborates an empirical study of Spanish HEIs. Spanish context is an interesting case study because the incorporation of the second and third missions was not a sequential procedure for universities. The paper addresses the following questions: Do missions cluster the set of activities developed by universities? Are university missions related? If so, what is the type of relationship that exists? Are indicators suited to their measurement? Which are the most appropriate indicators to explain them?

This paper seeks to make two contributions to the literature. Firstly, it explores the connection between the theoretical rationale of university missions and the practical implementation of indicators for their measurement. Secondly, we assess the complementarity among the universities' three missions by studying the relation among them.

2. Universities and their missions: an overview

2.1 The birth of the missions

Similar to society, the role of the university has evolving over time (Youtie and Shapira, 2008). The medieval university focused on teaching. Beginning in the nineteenth century, HEIs took on a more active role exemplified by the formation of Berlin's Humboldt University. The new university model attached importance to scientific research and the production of knowledge (Geuna, 1999). Teaching and research became the core of the 'classical' university at the time.

Later, a set of exogenous events led to changes in the modus operandi of universities. The most relevant was the adoption of a new mission, seen as complementary to the traditional missions of teaching and research and aimed at increasing the contribution of universities to the socioeconomic development of their environment (OECD, 2007). According to Molas-Gallart *et al*. (2002, p.2) the 'third mission' is defined as "the generation, use, application and exploitation of knowledge and other university capabilities outside academic environments", i.e., the interactions between universities and their socioeconomic environment (ISEE). These three missions are now considered to be inseparable and are carried out in an interconnected way by HEIs. Then the first hypothesis:

Hypothesis 1: Universities' activities cluster in three missions: teaching, research and the 'third mission'.

2.2 University missions and their controversial relationship

The addition of academic research as a core university mission entailed acceptance of compatibility and even complementarity with traditional teaching (Geuna, 1999). However some authors show that this relationship was far from obvious. Some propose a positive relation between teaching and research (Colbeck, 1998), others show a negative relationship (Barnett, 1992) and some deny any relation (Marsh and Hattie, 2002). Theoretical arguments reinforce the negative relation. Sample (1972) argues that specialization is one of the reasons for this link: research is highly specialized whereas teaching has to be broad.

When the third mission emerged the literature focused on analysis of its relation with research activities, and the complex relations with the private sector became especially relevant: dissemination

of knowledge and autonomy (Nelson, 2004) versus financial interest (Noble, 1977) or short-long term. However, just as teaching and research have become integrated, it seemed logical that the third mission should be similarly incorporated (Etzkowitz, 2004). The debate on the effect of ISEE in scientific production remains open. It has been argued that engagement in university-industry relations produces high quality research output (Etzkowitz and Leydesdorff, 2000) because these activities have complementary effects.

Study of the relationship between the first and the third missions is scarce and the literature provides no clear evidence on it. Ormerod (1996) argues from a theoretical point of view that there is strong complementarity among research, teaching and consultancy. However Landry (2010) finds that, in practice, there is a substitution effect between teaching and publications, complementarity between the latter and ISEE, and absence of a relation between the activities of the first and third missions.

We formulate a set of sub-hypotheses to identify the relationship among the university missions:

Hypothesis 2a: Teaching is negatively related to (substitute for) research.
Hypothesis 2b: Research is positively related (complementary) to the third mission.
Hypothesis 2c: There is no relation between the first and third missions (independents).

2.3 Indicators as measurement of the missions

The study of university 'mission' is mostly theoretical given that this concept is rather abstract and difficult to measure. This is an inherent difficulty in trying to achieve a consensus to develop and use indicators for their measurement (Bonaccorsi and Daraio, 2007).

One of the most important byproducts of universities is human capital (Duch and García-Estévez, 2011) and graduates are one of the principle mechanisms facilitating knowledge spillovers from universities (Audretsch *et al.*, 2005). For this reason number of enrolled students and graduates are often used as indicators of education production (Daraio *et al.*, 2011). Financial resources notably influence the activities of universities (Landry *et al.*, 2010). According to him funding relies on three sources: teaching revenues (part of internal university resources), funding from university research, and funding from industry.

Hypothesis 4a: The first mission is a construct that is determined by three indicators: enrolled students, graduates and teaching revenues.

Some authors consider that both undergraduate and postgraduate students are associated with teaching activities (Beasley, 1995). However within the Spanish context the postgraduate phase, which is characterized by masters and doctoral students, and production of theses, is related mainly with the second mission (Palomares-Montero *et al.*, 2012). The most widely used indicator to quantify research performance is number of publications (Giese, 1990). Although publications in journals included in the Institute for Scientific Information (ISI) is a frequently used measure, some authors consider that a broader range of publications and indicators is needed for the social science and humanities fields (Nederhof, 2006). For this reason, the inclusion of articles published in scholarly journals, or distinguishing the internationality of the journal is necessary. As suggested above, research funding is an important aspect in the characterization of second mission activities. In this case, financial resources have a public and competitive character and are studied generally in terms of number of research projects financed by competitive public grants or the income derived from them (Bozeman and Gaughan, 2007).

Hypothesis 4b: The second mission is a construct that is determined by several indicators: postgraduate students (masters and PhD), number of theses, number of research projects, research project income, and publications (in Spanish, foreign and ISI journals).

A specific case of research projects are those in which non-academic agents, specifically firms, collaborate. Molas-Gallart (2002) considers non-academic research collaborations as activities related to both the second and third missions. Patents also present duality because they are often treated as a natural research output (Etzkowitz, 1998), related to the university's second mission, but sometimes are considered a scientific finding to be commercially exploited (Meyer-Krahmer and Schmoch, 1998), related to the third mission. This latter view is related closely to royalties, the mechanism occasionally used to measure university-industry interaction (Thursby and Thursby, 2002). But third mission activities encompass other mechanisms (D'Este and Patel, 2007): consultancy activities (Link *et al.*, 2007); contracts and research and development (R&D) projects (Bozeman and Gaughan, 2007) and spin-offs (Landry *et al.*, 2007). Income from these activities reverts to the universities as contract research revenue and is also used to measure the third mission (Molas-Gallart and Castro-Martínez, 2007). Certain activities related to teaching are also linked to the third mission if non-academic agents participate. This is the case of training activities; under-graduate students work in companies (Molas-Gallart, 2002). But analysis of this as a third mission activity has been rather ignored.

Hypothesis 4c: The third mission is a construct involving several indicators: training students, applied and granted patents, collaboration on academic research, contract research income, number and revenues of R&D contracts and consultancies, royalties and spin-offs.

3. Empirical analysis

3.1 Spanish context

According to Larédo (2007) a country's institutional framework is particularly important in the evolution of the university's missions. This study is based on the Spanish context, which is a particular case in the incorporation of missions into the universities.

In countries such as Germany, France and the United States, research and ISEE were incorporated into the university missions as a sequential procedure. However, in Spain, the introduction of the second and third missions was not a gradual process. The 1983 Reform of Higher Education promoted research in the universities and introduced incentives for conducting contract R&D with socioeconomic agents. The Spanish science and technology policy was based on the injection of funds which had a significant impact on the outputs of universities. The abrupt appearance of research and ISEE as part of the university's missions did not question the potential impact on teaching. Their introduction ex alto implicitly assumed a positive relation between research and ISEE, which reinforces the complementarity hypothesis.

The Spanish higher education sector includes 73 universities. 48 are public institutions and 25 are private. Universities are some of the most important agents in the Spanish R&D system with 26.8% of total R&D expenditure, accounting for 47.1% of employment of full time researchers in 2008. But the majority of this contribution is due to public universities, which represent a quarter of total R&D expenditures and almost half of the researchers in Spain (INE, 2008b). The importance of these institutions in the Spanish research system places them at the center of this work. Excluding the National Distance Education University, our study population is composed of the remaining 47 HEIs.

3.2 Sources and variables

Table 1 presents the indicators used and their definitions. The third column of the table includes the sources. Data are for 2007 and 2008 and we use the cumulative value of the indicator measures for each university. The typology of the region in which the university is located can positively influence size and the indicators related to students. To avoid biased results and to control for university size, the indicators for students (enrolled and graduates) and teaching revenues are divided by the number of researchers.

Table 1: Definition of the variables and descriptive statistics

VARIABLE	DEFINITION	Source	Mean	S.D.	Min.	Max.	N
Enrolled students	Number of enrolled students in pre-graduated courses divided by number of doctors	MEC[a]	38	10.3	21.3	92.0	47
Graduates	Number of graduated students in pre-graduated courses divided by number of doctors	INE[b]	5.3	1.0	3.5	7.1	47
Teaching revenues	Revenues (thousands of Euros) from teaching activities divided by number of doctors	CRUE[c]	17.4	3.4	11.9	28.2	47
Training students	Number of students carrying out practices at enterprises during their pre-graduated studies	CRUE	1.822	1.874	196	11.065	43
Master students	Number of master students	INE	1.472	1.293	5	6.165	47
PhD students	Number of PhD students	INE	2.540	2.821	342	17.805	47
Theses	Number of doctoral theses that was reading	CRUE	146.5	124.8	19	536	44
Research project income	Revenues (thousands of Euros) from research activities (projects. subventions. …) from public administrations fundamentally	CRUE	20.251	15.727	1.761	66.967	47
Research projects	Granted research projects	CRUE	68.9	48.5	11	227	43
Spanish publications	Number of publications in Spanish journals	CRUE	383.5	396.6	8	1.590	38
Foreign publications	Number of publications in foreign journals	CRUE	890.2	660.1	50	2.861	38
ISI publications	Number of publications that were published in journals included in Journal Citation Report (JCR)	CRUE	854.9	647.9	17	2.425	37
Applied patents	Number of applied patents	OEPM[d]	19.5	17.2	2	80	47
Granted patents	Number of granted patents by Spanish Patent and Trademark	RedOTRI[e]	9.4	10.4	0	44	46
Collaboration with firms	Revenues (thousands of Euros) from research projects where firms participate	RedOTRI	4.978	8.154	0	47.598	39
Contract research income	Revenues (thousands of Euros) from contracts research	CRUE	11.175	15.860	639	90.274	46
R&D contracts	Number of R&D contracts	RedOTRI	414.5	491	7	2.851	46
Revenues R&D contract	Revenues (thousands of Euros) from R&D contracts	RedOTRI	18.271	26.727	435	159.672	45
Consultancy	Number of consulting activities	RedOTRI	357.1	535.3	0	2.484	39
Revenues consultancy	Revenues (thousands of Euros) from consulting activities	RedOTRI	2.166	5.058	0	30.758	40
Royalties	Patents revenues	RedOTRI	85.1	153.2	0	871	46
Spin-off	Number of new spin-off	RedOTRI	5	6.7	0	31	44

Source: Own elaboration from: [a] Ministry of Education (MEC, 2008); [b] Spanish National Institute (INE, 2007; 2008a); [c] Conference of Spanish University Rectors (CRUE, 2008); [d] Spanish Patent and Trademark (OEPM, 2011); [e] Survey RedOTRI (RedOTRI, 2007; 2008).

3.3 Analysis

We ran an Exploratory Factor Analysis (EFA) to cluster activities that distinguish among university missions and subsequently we conducted a Confirmatory Factor Analysis (CFA) based on Structural Equation Modeling, to test the complementarity among missions and the validity of the indicators proposed to measure them.

EFA identifies the minimum number of dimensions used to explain the maximum amount of information (Hair *et al.*, 1998) and involves principal components analysis (Varimax rotation; Kaiser normalization). The theoretical model for the CFA is presented in Figure 2. The advantage of this methodology lies in the possibility of measurement abstract concepts (constructs) and the indication conceding a possible relation. Following Olsson *et al.* (2000), we use Generalized Least Squares (GLS) to test our model with few observations.

EFA is not too restrictive with respect to the variable assumptions (Hair *et al.*, 1998) but the results can be affected by different units of measurement (Salvador-Figueras and Gargallo-Valero, 2006). On the other hand, CFA requires normal and independent variables (Ullman, 2000). Due to differences in the nature of our variables (Table 1) and to avoid problems in our results we used typified variables. We also applied data imputation techniques to replace missing values (the Expectation Maximization algorithm) in order to take account of the information from all universities.

4. Results and Discussion

Table 2 presents descriptive statistics. Spanish public universities, on average, had 38 enrolled students and 5.3 graduates per researcher in the two-years 2007 and 2008. The revenue from teaching activities was €17,000. Postgraduate students numbered 4,000 on average, with more than 60% PhD students and 40% masters. The average number of theses was 146. The funds for research come from the National Plan and universities obtained 70 research projects and €20 million on average. When firms participate in research, university research income reduces to a quarter. In

terms of publications, HEIs published over half in foreign and ISI journals and the remainder in Spanish journals. Spanish universities had less than 20 patent applications and less than 10 patents granted every year. Revenue from commercialization activities (royalties) reached just over €85,000 per university. Contract research income was €11 million and R&D contracts €18 million on average (total contracts, not per year). In 2007 and 2008 Spanish universities created 220 new spin-offs.

EFA identified three components explaining the 22 indicators; which correspond to the three university missions of teaching (third component), research (second component) and the third mission (first component). Since we know that the activities of the universities are partly represented, we can explain 63.7% of the total variability. Figure 1 shows the factor loadings in the rotated matrix according to the positioning of the indicators for each of the three factors.

The CFA model and the parameter estimates are depicted in Figure 2. Goodness of fit is determined mainly by the chi-squared statistic. A non-significant result implies adequacy of the final model. To complement it we use three incremental fit indices -NNFI, CFI and RMSEA- because they are likely to reject correct models when the number of observations is small (Hu and Bentler, 1999). Despite this limitation, we observe that the values for the first two indices are above 0.95, and are below 0.05 for the last one, which indicates good model fit.

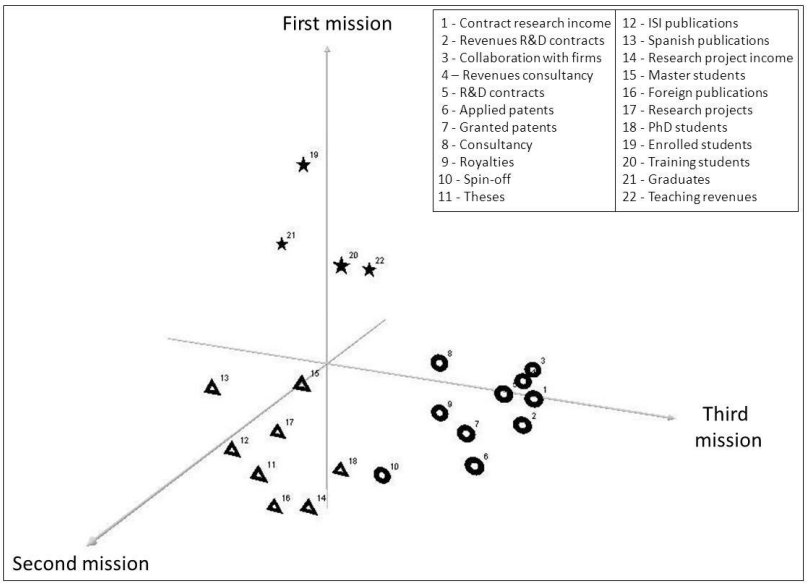

Figure 1: Results of the Exploratory Factor Analysis

The correlation among latent variables captures the relationship among missions and provides the most striking finding in the study. All coefficients are significant. There is a positive relationship between the second and third missions but it is negative between these two missions and teaching. That is, there is a relationship between all the university's missions so that research and ISEE are complementary but show a substitution effect with teaching.

Figure 2 shows the factor loadings (standardized solution) from the CFA. Their significance indicates the validity of the indicators for explaining each construct. The chi-squared statistics, obtained for the standardized solution in each structural equation, capture the importance of the indicator for explaining mission variability.

The indicators related to undergraduate students and teaching revenues in the first mission are valid to explain this construct. In this case, the number of enrolled students per researcher explains the highest percentage of variability (99.7%). Although apparently postgraduate students are part of a student's education stages, these indicators are more relevant to the second mission in the case of

the Spanish public universities. This means that masters and PhD students (in public universities) have a greater research than professional component.

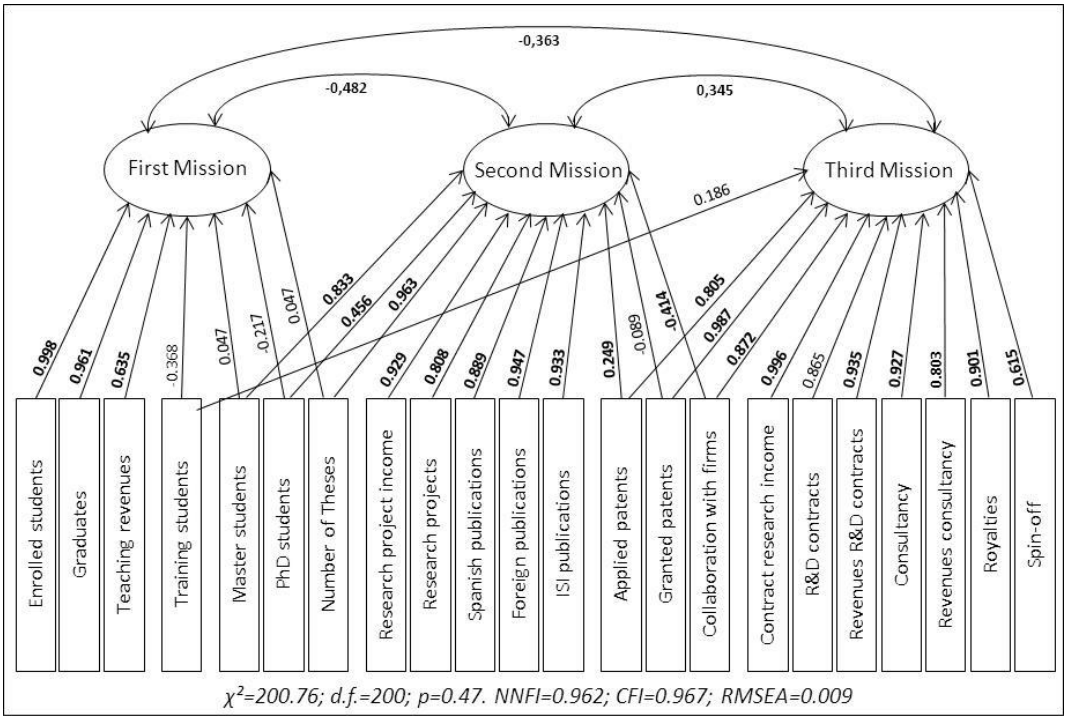

Figure 2: Structural Equations Modeling for the Confirmatory Factor Analysis

Publications in foreign and ISI journals have the highest explanatory power for research (89.7% and 87.1% respectively). Patent applications refer to both the second and third missions (although the scores lie more on the side of the latter). However, granted patents are only significantly related to the third mission. These results categorize them as a scientific finding to be commercially exploited, in accordance with Meyer-Krahmer and Schmoch (1998). Granted patents also show a negative sign, but no significant, in relation to the second mission, meaning that they are not related to the indicators measuring research. This result can be explained by the 'secrecy problem' (Florida and Cohen, 1999) which refers to the tighter restrictions on the publication of research findings. Publications allow researchers disseminate the knowledge while patents protect research outputs and the results are not accessible for the wider society. On the other hand, while research project income may explain the second mission, collaborative projects with firms show a negative and significant relationship with research and a positive and significant with ISEE. The 'skewing problem' (Florida and Cohen, 1999) explains this result. Skewing refers to the alleged shift in research efforts from basic to applied research. In this case, while universities develop research as an end in itself leading to more basic projects, firms are more worried about its application and their financial rewards (Noble, 1977).

The majority of indicators for the third mission are mostly statistically significant. The variability explained by contract research income is 99.1%, while by granted patents is 92%. The indicator for training students is not significant for either mission.

5. Conclusions

Each university is the result of different processes of social, economic and cultural development. In the modern knowledge societies, universities contribute to economic development though fulfillment of these three missions (OECD, 2007) and it is commonly accepted that they are key repositoires of new knowledge and human capital. However the complementarity among missions was taken as given when the second and the third missions were introduced in HEIs. This paper claims the

attention over potentially unrealistic expectations over the capacity of universities to fulfill all these roles at the same time.

The present study on Spanish public universities provides an overview of the impact of all three missions. Our results suggest that greater efforts on research or ISEE activities are mutually beneficial but are detrimental to teaching. This strengthens the necessity to focus on single missions to achieve quality and excellence. This is the model that has been proposed by both academics and policy makers who believe that each university should develop a specialized focus on only one mission (Geuna, 1999; EC, 2005). Different models of a modern university are possible because HEIs are out of date and urgently need modernizing if they want to play their part in Europe's drive for more growth (EC, 2006; David and Metcalfe, 2007). Rethinking whether all HEIs should be simultaneously developing all three missions may be vital to ensuring their contribution to the socio-economic development of regions.

The Spanish model of the university-ISEE relationship rests on contracts (mostly R&D contracts), which contrasts with the American model which is based on patents (AUTM, 2010). Although the experience in the US shows that too much emphasis by HEIs on acquiring and exploiting intellectual property rights can hamper knowledge-sharing and collaborative research with the business sector (David and Metcalfe, 2007), Spanish evaluation system continues to attach great importance to patenting and licensing activities and patents granted pursue economic exploitation as per the proposal in Meyer-Krahmer and Schmoch (1998). Narrow policy emphasis on other linkages may obscure not only the presence of other types of university-industry interactions that are less visible but are equally and even more important (D'Este and Patel, 2007).

Human capital creation is one of the most important activities developed by universities because graduates are one of the principle mechanisms facilitating knowledge spillovers and the principal connection between firms and universities. Training students are a mechanism to link universities and firms, but in the Spanish context this activity is not developed in an appropriate way by the universities, because this indicator is not suitable for the measurement of any missions. This means damage for the industry because do not only have less access to knowledge of recent scientific research but also do not receive enough abilities to solve complex problems, perform research and develop ideas (Salter and Martin, 2001). While it is true that finding a balance between the objectives of the academic and business worlds is not easy, it is necessary for universities' activities to be successful. In fact the collaboration between firms and universities benefits both: enterprises improve the probability of innovative outcomes and HEIs seemingly have a more significant impact than any other type of collaborative partner. The equilibrium should involve: developing an understanding of industrial practice and providing an education that equips students with more generic and long-lasting skills (Salter and Martin, 2001); open dissemination of scientific knowledge for the advancement of science and tighter restrictions on the publication (Tartari et al., 2012); and autonomy to establish researchers agendas and application and firms' financial rewards (Noble, 1977). Future research should integrate a functional dimension to check the effect of these results on externalities in the region in order to test if the detrimental effect of teaching is indirectly decreasing the impact of HEIs on the expected economic growth.

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